TOMATO SOUP PREMIX BASE: DEVELOPMENT AND OPTIMISATION USING RESPONSE SURFACE METHODOLOGY

Rupesh S. Chavan[a], Anit Kumar[b] *and* Shraddha Bhatt[c]

[a]Department of Food Science and Technology, Assistant Professor,
National Institute of Food Technology Entrepreneurship and Management (NIFTEM),
Kundli, Sonepat, Haryana, India

[b]Department of Food Science and Technology, National Institute of Food Technology Entrepreneurship and Management (NIFTEM), Kundli, Sonepat, Haryana, India

[c]Anand Agricultural University, Anand-(Gujarat) India.

ABSTRACT

The optimum formulation for production of tomato soup premix base was determined using Response Surface Methodology (RSM Design Expert DX 6). Effect of addition levels of tomato powder, whey powder, sugar and salt along with fixed ingredients including citric acid, skim milk powder, cream powder and yeast extract on sensory attributes were investigated. Significant regression model was determined which explained the effect of changes in the concentration of the variables on responses of the tomato soup premix base. The coefficient of determination, R^2 of all response variables were higher than 0.8. The optimized formulation given by RSM, based on response surfaces and superimposed plots, was further analysed for sensory analysis.

Key words: Tomato powder, Whey Powder, Soup, Functional Property.

Introduction

Whey based soup can be manufactured and formulated keeping in consideration the nutritional values, biological and functional properties. Whey can be used in manufacturing of soup in larger amounts due to the following reasons; a. whey has a broad range of solubility i.e. from pH 3-8, b. whey does have a bland flavor and on many occasion they can act as carrier for the aroma compounds, c. buffering capacity of whey can be explored for survival of proboitic bacteria in the gastro intestinal tract, d. addition of whey improves the

'mouthfeel' of the drink by increasing the viscosity of the beverage, e. coagulation of whey proteins during thermal treatments, f. higher viscosity of concentrates affect the effectiveness of thermal treatments, g. high content of minerals in the whey are responsible for undesired salty-sour flavour of whey.

One of the most appealing aspects of whey proteins is that they can serve as a functional ingredient in a food system. Protein functionality is defined by Morr and Ha (1993) as "physicochemical properties that influence the structure, appearance, texture, viscosity, mouth feel, or flavor retention of the product". Whey protein functionalities can be influenced by many factors including the composition and processing of the whey protein as well as the composition and processing of the food system (Morr and Ha, 1993).

In the present investigation efforts are made to standardize the process for preparation of tomato soup premix and optimization of the process parameters for spray drying of the tomato soup premix. The tomato soup powder base was developed by using whey powder, tomato powder, salt, sugar, yeast extract, citric acid, skim milk powder, natural creamear and flavour. The prepared tomato soup premix base was then reconstituted and was evaluated for its sensory characteristics. The process of formulation of the tomato soup premix base was standardized on the basis of monitorable optimized parameters in coordination with prepared food grade additives with the help of response surface methodology.

2. Materials and methods

2.1 Materials:

For preparation of tomato soup premix base: whey powder, sugar, citric acid, skim milk powder and salt were supplied by M/s Gulati, Delhi. Spray dried tomato powder was supplied by M/s Aarkay Food Products Ltd., Ahmedabad. Cream Powder and yeast extract were procured from M/s Duke Thompson, Delhi and M/s Symega, Kerala respectively.

2.2 Experimental design:

Response surface methodology (RSM) is adopted in the experimental design as it emphasizes the modelling and analysis of the problem in which response of interest is influenced by several variables, and the objective is to optimize this response (Montgomery, 2001). Experimental central composite (face-centered) design was done by using Design Expert (DX) version 6 with three coded levels. A three-level, four-factor central composite

rotatable design was employed. The independent variables selected for the set of experiments were: tomato powder, *X1,* 30, 32 and 34 gm; whey powder, *X2,* 38,40,and 42 gm; salt, *X3,* 9,10 and 11 gm and sugar, *X4,* 10,11 and 12 gm and the other ingredients which were added and kept in a constant ratio were citric acid (1 gm), skim milk powder (2 gm), cream powder (2 gm) and yeast extract (2 gm). The variables and their levels were chosen based on the limited literature available on dry soup mix (Black *et al.,* 1969), shelf stable tomato soup concentrates (Glasser *et al.,* 1972); soup concentrates (Glaser and Sjonvall 1979), free radical interactions between raw materials in dry soup powder (Raitio *et al.,* 2011); sensory characteristics and rheological properties of soups containing oat and barley β-glucan before and after freezing (Lyly *et al.,* 2004). The actual value of each level is detailed in Table 1. The three levels of the process variables were coded as −1, 0, 1 (Montgomery, 2001) and design in coded (*x*) form and at the actual levels (X) is given in Table 2.

Table 1: Extreme level of independent variables used for optimization of tomato powder, whey powder, salt and sugar for preparation of tomato soup premix base.

Independent Variables	Code	Unit	Levels of addition		
			-1	0	+1
Tomato Powder	X1	gm	30	32	34
Whey powder	X2	gm	38	40	42
Salt	X3	gm	9	10	11
Sugar	X4	gm	10	11	12

Table 2: Central composite rotatable experimental design employed for preparation of tomato soup premix base.

S.	Coded Variables				Uncoded Variables (gm)			
No	*x1*	*x2*	*x3*	*x4*	Tomato Powder	Whey Powder	Salt	Sugar
1	-1	-1	-1	-1	30	38	9	10
2	1	-1	-1	-1	34	38	9	10
3	-1	1	-1	-1	30	42	9	10
4	1	1	-1	-1	34	42	9	10
5	-1	-1	1	-1	30	38	11	10
6	1	-1	1	-1	34	38	11	10
7	-1	1	1	-1	30	42	11	10
8	1	1	1	-1	34	42	11	10
9	-1	-1	-1	1	30	38	9	12
10	1	-1	-1	1	34	38	9	12
11	-1	1	-1	1	30	42	9	12
12	1	1	-1	1	34	42	9	12

13	-1	-1	1	1	30	38	11	12
14	1	-1	1	1	34	38	11	12
15	-1	1	1	1	30	42	11	12
16	1	1	1	1	34	42	11	12
17	-2	0	0	0	28	40	10	11
18	2	0	0	0	36	40	10	11
19	0	-2	0	0	32	36	10	11
20	0	2	0	0	32	44	10	11
21	0	0	-2	0	32	40	8	11
22	0	0	2	0	32	40	12	11
23	0	0	0	-2	32	40	10	9
24	0	0	0	2	32	40	10	13
25	0	0	0	0	32	40	10	11
26	0	0	0	0	32	40	10	11
27	0	0	0	0	32	40	10	11
28	0	0	0	0	32	40	10	11
29	0	0	0	0	32	40	10	11
30	0	0	0	0	32	40	10	11

2.3. Preparation of Tomato soup sample:

Optimum levels of tomato powder, whey powder, salt and sugar were evaluated by conducting the **s**ensory analysis. The dry ingredients were weighed and then mixed in a Planetary Mixer (Nutech Engg. Cooporation, New Delhi) for a period of 5 min followed by shifting it through a 36 mesh size sieve to remove any unwanted lumps. The samples were than packed in standup pouches of polyethylene bags at room temperature. Soup premix powder (50 gm) was dissolved in 450 ml lukewarm water with continuous mixing which was followed by increasing the temperature to boiling and holding for 3 min. Prepared soup was served in hot condition at about 70 ^{O}C for 5 panelist who assessed the soup for appearance, odour, texture, flavor and after flavor, and to mark on a Hedonic Rating Test (1 – Dislike extremely, 5 – Neither like nor dislike and 9 – Like extremely) in accordance with their opinion**.**

3. Results and Discussions

3.1. Effect of ingredients on appearance of tomato soup premix base:

Regression model fitted to experimental results of appearance (Table 3) had an F-value of 14.1122 and a significance of $P < 0.0001$. The fit of model was also expressed by the coefficient of determination R^2, which was found to be 0.92943, indicating that 92.943 % of

the variability of the response was explained by the model. The quadratic model obtained from regression analysis is as follows:

Appearance = 7 + 0.541667 * tomato powder + 0.125 * whey powder + 0.041667 * salt - 0.04167 * sugar - 0.65625 * tomato powder^2 - 0.28125 * whey powder^2 - 0.28125 * salt^2 - 0.28125 * sugar^2 - 0.0625 * tomato powder * whey powder + 0.0625 * tomato powder * salt - 0.0625 * tomato powder * sugar - 0.1875 * whey powder * salt + 0.1875 * whey powder * sugar + 0.0625 * salt * sugar.

Sum of squares of the tomato powder proves that appearance is significantly affected by the increasing level of tomato powder (Table 3, Fig 1). The interaction between whey powder-salt (Fig 2) and whey powder-sugar (Fig 3) had a significant effect on appearance. Other interactions were not significant (P > 0.05). Appearance of the tomato soup premix base increased with increase in concentration of tomato powder, whey powder and salt. The colour of the tomato soup premix base may be due to the presence of whey protein that completely binds lycopene during processing and also retains during the storage as reported by Ahmed et al. (2012) in cheese whey permeates fortified with fresh cut tomato.

Table 3: ANOVA for appearance, odour and texture of tomato soup premix base

Source	Sum of Squares	DF	Appearance		Odour		Texture	
			Mean Square	F Value	Mean Square	F Value	Mean Square	F Value
Model	23.05	14	1.646429	14.1122	1.46071	9.73809	2.675	10.2446
A	7.04166	1	7.041667	60.3571	1.04166	6.94444	7.04166	26.9680
B	0.375	1	0.375	3.21428	0.375	2.5	0.04166	0.15957
C	0.04166	1	0.041667	0.35714	2.04166	13.6111	5.04167	19.3085
D	0.04166	1	0.041667	0.35714	0.04166	0.27777	0.04166	0.15957
A^2	11.8125	1	11.8125	101.25	0.66964	4.46428	7.14583	27.3670
B^2	2.16964	1	2.169643	18.5969	0.66964	4.46428	1.86011	7.12386
C^2	2.16964	1	2.169643	18.5969	7.74107	51.6071	7.14583	27.3670
D^2	2.16964	1	2.169643	18.5969	7.74107	51.6071	7.14583	27.3670
AB	0.0625	1	0.0625	0.53571	0.5625	3.75	5.0625	19.3883
AC	0.0625	1	0.0625	0.53571	0.5625	3.75	1.5625	5.98404
AD	0.0625	1	0.0625	0.535714	0.5625	3.75	0.5625	2.154255
BC	0.5625	1	0.5625	4.821429	0.0625	0.416667	0.5625	2.154255
BD	0.5625	1	0.5625	4.821429	0.0625	0.416667	0.5625	2.154255
CD	0.0625	1	0.0625	0.535714	1.5625	10.41667	0.0625	0.239362
Residual	1.75	15	0.116667		0.15		0.261111	
Lack of Fit	1.75	10	0.175		0.225		0.391667	
Pure Error	0	5	0		0		0	

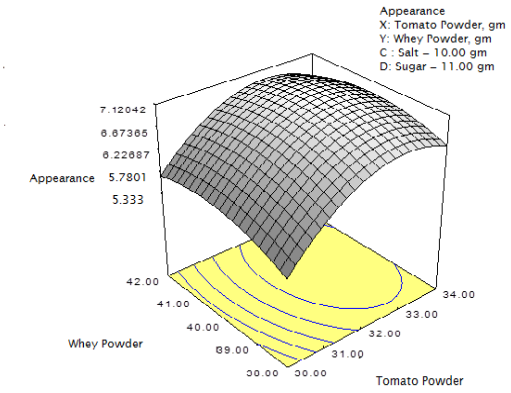

Figure 1: Effect of tomato powder and whey powder on the appearance of tomato soup premix

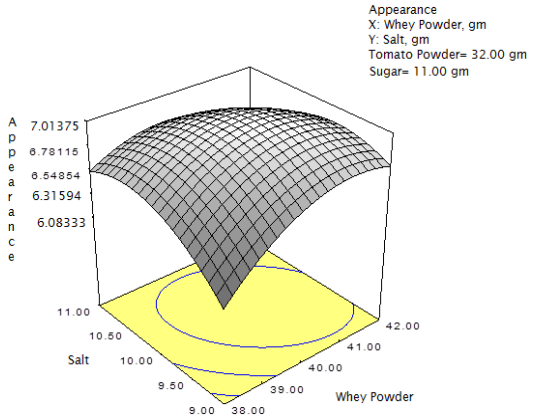

Figure 2: Effect of whey powder and salt on the appearance of tomato soup premix

3.2. Effect of base ingredients on odour of tomato soup premix base:

The regression model fitted to experimental results of odour (Table 3) has a F-value of 9.738095). The quadratic model obtained from regression analysis for odour in terms of coded levels of the variables is as follows:

Odour = 6 + 0.208333* tomato powder - 0.125 * whey powder + 0.291667 * salt + 0.041667 * sugar - 0.15625* tomato powder^2 -0.15625* whey powder^2 - 0.53125 * salt^2 - 0.53125 * sugar^2 - 0.1875 * tomato powder * whey powder - 0.1875 * tomato powder * salt + 0.1875 * tomato powder * sugar + 0.0625 * whey powder * salt - 0.0625* whey powder * sugar - 0.3125* salt * sugar

Sum of squares of the tomato powder and salt reveals that (Fig 3) it is significantly affecting the odour at a much significant level. Similarly, interaction between salt-sugar (Fig 4) had a significant effect on odour. Other interactions were not significant ($P > 0.05$) to affect the odour of the tomato soup powder base. Odour increased with increase in concentration of tomato powder, salt and sugar. On the other hand odour of the sample was affected negatively with increased in the concentration of whey powder and the reason may be attributed to the presence of whey proteins which when used as a functional ingredient in a food system like soup are often responsible for affecting the flavor retention property (Morr et al., 1993).

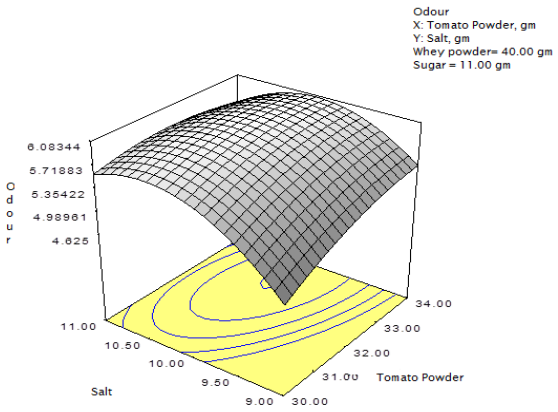

Figure 3: Effect of tomato powder and salt on the odour of tomato soup premix

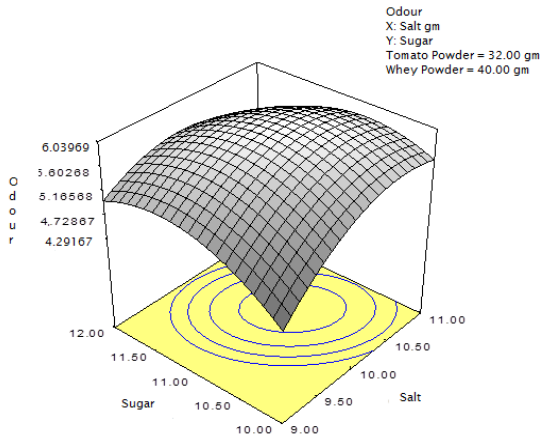

Figure 4: Effect of salt and sugar on the odour of the tomato soup premix

3.3. Effect of base ingredients on texture of tomato soup premix base:

Texture acceptability mainly depends on hydrocolloid concentration that is present in premix base and also on ration of tomato powder in the tomato soup premix base. Regression model fitted to experimental results of texture (Table 4.3) had an F-value of 10.24468. The quadratic model obtained from regression analysis for texture in terms of coded levels of the variables is as follows:

Texture = 8 + 0.541667 * tomato powder - 0.04167 * whey powder + 0.458333 * salt - 0.04167 * sugar - 0.51042 * tomato powder^2 - 0.26042 * whey powder^2 - 0.51042 * salt^2 - 0.51042* sugar^2 + 0.5625 * tomato powder * whey powder + 0.3125* tomato powder * salt - 0.1875 * tomato powder * sugar + 0.1875 * whey powder * salt + 0.1875 * whey powder * sugar - 0.0625 * salt * sugar

Concentration of tomato powder and salt had a significant effect on the texture of the soup premix base. The magnitude of p-value in the Table 3, indicated that linear terms of process variable tomato powder and salt, quadratic terms tomato powder^2, whey powder^2, sugar^2 and salt^2 were significant to affect the texture of the soup. The interaction between whey tomato powder-whey powder and tomato powder-salt (Fig 5 and 6) had a significant effect on texture of the reconstituted tomato soup and was in total agreement with the results reported for tomato concentrate by Harper et al. (2006). Texture is also affected by the concentration of hydrocolloids/ whey powder in premix base, as reported by Unal *et. al.* (2003) for set yoghurt and by Fernandez (2007), Pichler (2012), Bugaud (2013), Igual (2014).

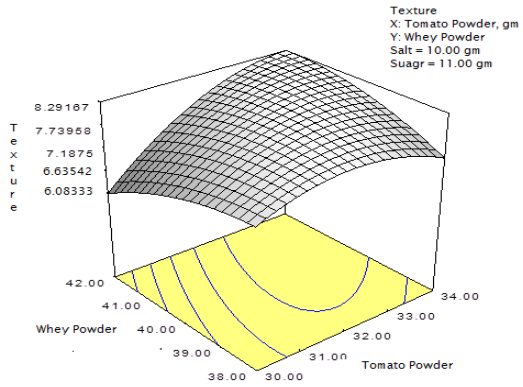

Figure 5: Effect of tomato powder and whey powder on the texture of tomato soup premix

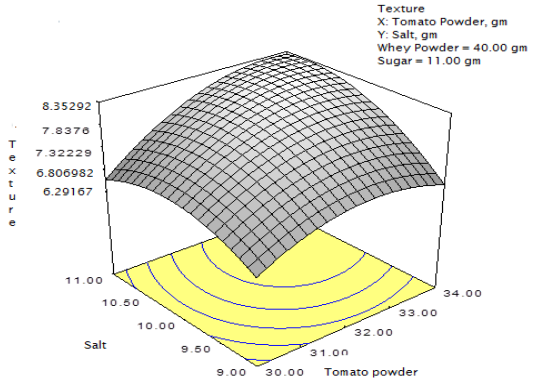

Figure 6: Effect of tomato powder and salt on the texture of tomato soup premix

3.4. Effect of base ingredients on taste of tomato soup premix base:

The ANOVA results are presented in Table 4 and the quadratic model obtained from regression analysis for taste can be determined as follows:

Taste = 7.666667 + 0.333333* tomato powder - 0.08333 * whey powder - 0.08333 * salt - 0.08333 * sugar - 0.5625 * tomato powder^2 - 0.5625 * whey powder^2 - 0.9375 * salt^2 - 0.5625 * sugar^2 - 0.125 * tomato powder * whey powder + 0.25 * tomato powder * salt + 0.125 * tomato powder * sugar + 0.625 * whey powder * salt - 0.25 * whey powder * sugar + 0.125 * salt * sugar

Table 4: ANOVA for taste, flavour and after flavour of tomato soup premix base

Source	Sum of Squares	DF	Taste		Flavour		After Flavour	
			Mean Square	F Value	Mean Square	F Value	Mean Square	F Value
Model	23.05	14	3.47261	10.9661	3.68214	10.1967	2.36666	9.68181
A	7.04166	1	2.66666	8.42105	2.04166	5.65384	1.5	6.13636
B	0.375	1	0.16666	0.52631	0.04166	0.11538	0	0
C	0.04166	1	0.16666	0.52631	2.04166	5.65384	0.16666	0.68181
D	0.04166	1	0.16666	0.52631	0.375	1.03846	0.66666	2.72727
A^2	11.8125	1	8.67857	27.4060	11.8125	32.7115	6.85714	28.0519
B^2	2.16964	1	8.67857	27.4060	7.74107	21.4368	15.4285	63.1168
C^2	2.16964	1	24.1071	76.1278	22.5267	62.3818	10.7142	43.8311
D^2	2.16964	1	8.67857	27.4060	11.8125	32.7115	3.85714	15.7792
AB	0.0625	1	0.25	0.78947	0.5625	1.55769	0.25	1.02272
AC	0.0625	1	1	3.15789	0.0625	0.17307	0.25	1.02272
AD	0.0625	1	0.25	0.789474	1.5625	4.32692	1	4.09090
BC	0.5625	1	6.25	19.73684	3.0625	8.480769	0	0
BD	0.5625	1	1	3.157895	0.0625	0.173077	2.25	9.20454
CD	0.0625	1	0.25	0.789474	3.0625	8.480769	0.25	1.02272
Residual	1.75	15	0.31666		0.361111		0.244444	
Lack of Fit	1.75	10	0.34166	1.28125	0.458333	2.75	0.366667	

Pure Error	0	5	0.26666	0.166667	0

The coefficient value of linear term tomato powder is positive signifying that it increases the taste of tomato soup premix base. While, the coefficient values of linear term whey powder, salt and sugar are negative (Fig 7 and 8), which shows that any increase in the value of this will decrease the taste. Whey proteins is used as a functional ingredient in a food system like soup and are often responsible for affecting the structure, appearance, texture, viscosity, mouth feel, or flavor retention property (Morr et al., 1993). Functionality of whey proteins is generally affected by factors like: temperature, pH, protein concentration, salt, sugars, calcium, and free sulfhydryl groups in the system (Jayaprakasha et al., 1999; Rich et al., 2000; Foegeding et al., 2002).

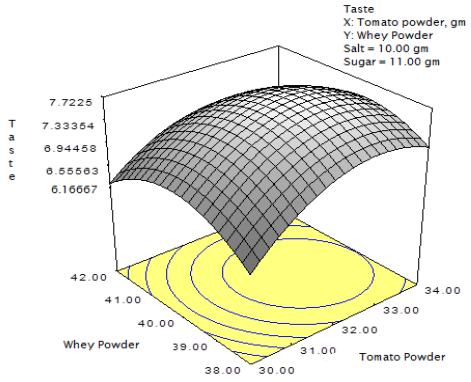

Figure 7: Effect of tomato powder and whey powder on the taste of tomato soup premix

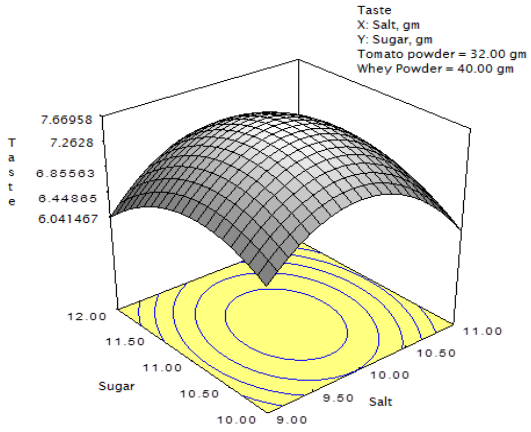

Figure 8: Effect of salt and sugar on the taste of the tomato soup premix

3.5. Effect of base ingredients on flavour of tomato soup premix base:

Flavour is another main attribute of the food product which increases the consumer acceptance. Regression model fitted to experimental results of flavour (Table 4) showed F-value of 10.1967 and was significant ($P < 0.0001$). The quadratic model obtained from regression analysis is as follows:

Flavour = 7.833333 + 0.291667 * tomato powder - 0.04167 * whey powder - 0.29167 * salt - 0.125 * sugar - 0.65625 * tomato powder^2 - 0.53125* whey powder^2 - 0.90625* salt^2 - 0.65625* sugar^2 - 0.1875* tomato powder * whey powder + 0.0625* tomato powder * salt + 0.3125* tomato powder * sugar + 0.4375* whey powder * salt - 0.0625* whey powder * sugar + 0.4375* salt * sugar

Flavour profile of tomato soup premix base was found to increase with increase in concentration of tomato powder and vice versa. While, the coefficient value of linear term whey powder, salt and sugar (Fig 9 and 10) are negative, signifying that any further increase in the value of these factors will decrease the flavour of the tomato soup premix base. All quadratic terms are negative which denotes that the model is quadratic. Premix base consists of sugar and increase in the sugar concentration enhances the consumer acceptance regarding flavour but whey proteins tend to decrease the same as reported by Gan (2007), Bugaud (2013) and by Igual (2014).

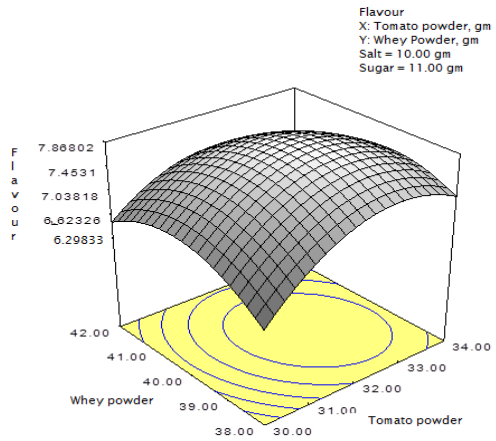

Figure 9: Effect of tomato powder and whey powder on the flavour of tomato soup premix

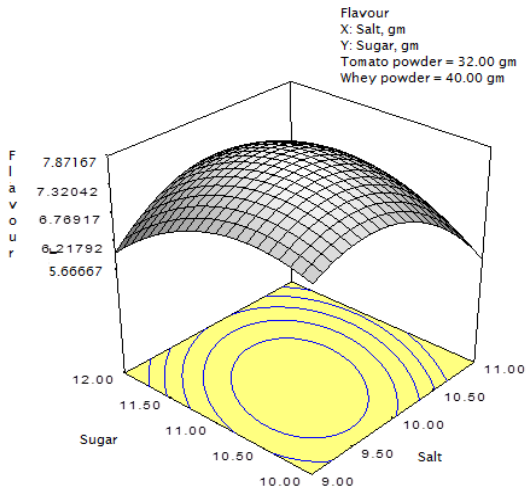

Figure 10: Effect of salt and sugar on the flavour of the tomato soup premix

3.6. Effect of base ingredients on after flavour of tomato soup premix base

Regression model fitted to experimental results of after flavour (Table 4) had an F-value of 9.681818. The quadratic model obtained from regression analysis for after flavour is as follows:

After flavour = 7 + 0.25 * tomato powder + 0 * whey powder - 0.08333 * salt - 0.16667 * sugar - 0.5 * tomato powder^2 - 0.75 * whey powder^2 - 0.625 * salt^2 - 0.375 * sugar^2 + 0.125 * tomato powder * whey powder + 0.125 * tomato powder * salt - 0.25 * tomato powder * sugar + 0 * whey powder * salt + 0.375 * whey powder * sugar - 0.125 * salt * sugar

After flavour was found to increases with increase in concentration of tomato powder and whey powder. While, the coefficient value of linear term salt and sugar was negative, which signifies that any increase in the value of these factors will decrease the after flavour

(Fig 11 and 12). Also all quadratic terms are negative denoting that the model is quadratic. Increasing sugar concentration increases the consumer acceptance regarding after flavour but whey proteins tend to decrease the same as reported by Gan (2007), Bugaud (2013) and by Igual (2014).

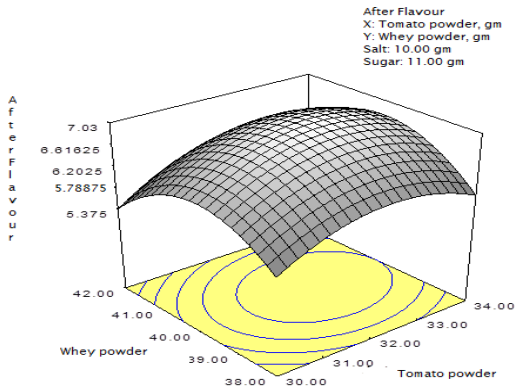

Figure 11: Effect of tomato powder and whey powder on the after flavour of tomato soup premix

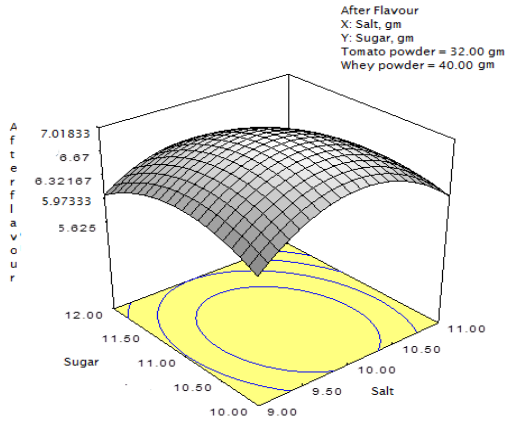

Figure 12: Effect of salt and sugar on the after flavour of the tomato soup premix

3.7. Compromised optimum condition for ingredients to develop tomato soup premix base:

The compromised optimum condition for the development of tomato soup premix powder as determined using Design expert Software (DX 6) for maximum: appearance, odour, texture, taste, flavour and after flavour is depicted in Table 5.

Table 5: Compromised optimum conditions for development of tomato soup premix base

No.	Tomato powder	Whey powder	Salt	Sugar	Appearance	Odour	Texture	Taste	Flavour	After flavour
1	34.00	42.00	9.87	11.13	6.67779	5.57058	8.14312	6.50599	6.6625	6.09855
2	34.00	42.00	10.02	11.30	6.66466	5.58629	8.25106	6.56835	6.69251	6.07775
3	34.00	42.00	10.11	11.09	6.66026	5.60269	8.3803	6.71941	6.7303	6.11467
4	34.00	41.97	9.94	11.18	6.68181	5.59503	8.20374	6.57204	6.70415	6.11796
5	34.00	42.00	10.13	11.29	6.65422	5.58776	8.34771	6.64863	6.71732	6.07153
6	34.00	42.00	10.09	10.82	6.63131	5.55083	8.36483	6.74725	6.66776	6.12088
7	34.00	42.00	10.58	10.83	6.49694	5.48979	8.67409	6.81811	6.44512	5.94862
8	33.92	42.00	9.97	10.28	6.49601	5.19092	8.01396	6.54287	6.33826	5.97302
9	34.00	42.00	10.07	11.95	6.49027	5.25325	7.85039	6.01958	6.27428	5.74095
10	34.00	42.00	9.35	11.31	6.58768	5.31375	7.40185	5.60919	6.07511	5.80907

The calculated values of responses and the predicted values for compromised optimum solutions given by RSM, are tabulated in Table 6. After analysis of the tomato soup premix base according to the formulation given by the RSM it was observed that, there was very less deviation in calculated values of responses and the predicted values for compromised optimum solution no 1. Thus, finalised optimum solution was solution no. 1 in Table no 5

Table 6: Comparison of response values given by RSM and actually calculated values

Appearance		Odour		Texture		Taste		Flavour		After flavour	
RSM	Actual	RSM	Actual	RSM	Actual	RSM	Actual	RSM	Actual	RSM	Actual
6.677	6.644	5.570	5.563	8.143	8.131	6.505	6.511	6.662	6.658	6.098	6.085
6.664	6.598	5.586	5.575	8.251	8.244	6.568	6.558	6.692	6.685	6.077	6.005
6.660	6.656	5.602	5.590	8.380	8.375	6.719	6.681	6.730	6.721	6.114	6.088
6.681	6.679	5.595	5.585	8.203	8.214	6.572	6.556	6.704	6.689	6.117	6.154

4. Conclusion

RSM is a useful tool in formulation and optimisation of the basic formulation of tomato soup premix base by partial differentiating the empirical model with respect to each parameter, equating to zero and simultaneously solving the resulting functions. The final optimised solution obtained for preparation of tomato soup premix base was consisting of 34 gm (Tomato Powder, 42 gm (Whey Powder), 9.87gm (Salt), 11.13 gm (Sugar) along with citric acid (1 gm), skim milk powder (2 gm), cream powder (2 gm) and yeast extract (2 gm). The optimised tomato soup premix base can be used for manufacturing of whey fortified tomato soup premix.

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